IV.—FLECHSIG: THE ROUTES OF CONDUCTION IN THE BRAIN AND CORD.

DIE LEITUNGSBAHNEN IM GEHIRN UND RUECKENMARK DES MENSCHEN AUF GRUND ENTWICKELUNGSGESCHICHTLICHER UNTERSUCHUNGEN, dargestellt von Dr. P. Flechsig. (*The conducting tracts in the brain and spinal cord of man on the basis of embryological researches.*) Leipzig, 1876.

Flechsig's researches are mainly based on the following laws, which, though not entirely new, had not been previously utilized to any extent in the study of the nervous system:

I. In the course of development of the central nervous system, the different distinct nerve-tracts are not formed simultaneously, but successively; the individual fibres, however, constituting any one nerve-tract, are formed at one and the same time.

II. The formation of the medullary sheaths takes place in the different tracts in the chronological order of the primary development of these tracts.

III. The mode of development of the central nervous system thus divides it into separate and distinct systems of fibres, (tracts). The most convenient method of studying the topography of the separate nerve-tracts during their development, is afforded by the formation of the medullary sheaths. The fasciculi, the nerves of which have become invested with the white substance of Schwann, are easily distinguished by their dull white appearance, from the other *gray* fibres, which consist, as yet, merely of an axis-cylinder. This characteristic appearance of developed medullary sheaths (for which F. adopts the term "Markweiss" (medullary white) is found for the first time about the middle of intra-uterine life; the process is completed about the end of the fifth month after birth. Although dissection of the fresh material shows the topography of the white nerve-bundles very distinctly, microscopical sections are of course of still more value, especially after staining with substances, like osmic acid, chloride of palladium and chloride of gold, which render all medullated fibres still more easily distinguishable by their color. The author also mentions a new method of staining with gold, which gives excellent results in tracing the course of nerve-fibres.

On the strength of embryological observations, the author divides the white substance of the spinal cord into the following territories: I., *the anterior pyramidal tract* (vordere Pyramidenbahn), a narrow zone lining the anterior fissure; II., *the main anterior fasciculus*, (Vorderstrang-Grundbundel) identical with the anterior column, with the exception of the previously mentioned zone; III., *Goll's columns*, the narrow triangular region on each side of the posterior fissure, also known previously as the funiculus gracilis, but merely in the cervical part of the cord; IV., *Burdach's columns*, (B.'s Keilstraenge) occupying the remainder of the posterior columns, and continuous with the fasciculus cuneatus in the medulla; V., *the direct lateral cerebellar tract* (direkte Kleinhirn-seitenstrangebahn), a narrow zone at the periphery of the lateral columns, extending from near the exit of the posterior roots to about the centre of the periphery of the lateral columns; VI, *the lateral crossed pyramidal tract* (gekreuzte Pyramiden-seitenstrangbahn), extending inwardly from V., to the posterior horn of the grey substance; VII., *the remainder of the lateral column* (Seitenstrangreste), which he subdivides into (a) *the lateral border-zone of the grey substance* (seitliche Grenzschichte der grauen Substanz), a narrow zone surrounding the lateral boundary of the grey substance, and (b) *the anterior mixed region of the lateral column* (vordere gemischte Seitenstrangzone), the remaining (anterior external) part of the lateral column.

In the fully developed cord these separate tracts are not visibly isolated; but, as Flechsig maintains, they may be recognized by the size of their nerve-fibres. By dividing nerve-fibres into four classes, according to their thickness, he finds that each region differs slightly from the neighboring territory in the size of the fibres constituting the bundle. But more interest centers in the fact that the course of the separate system of fibres, traced by means of the embryological method, is identical with the course assumed by the so-called *secondary degenerations* of Tuerck. Flechsig's results on the course of the tracts may be summed up as follows:

The Pyramidal Tracts. The fibres of each pyramid of the medulla oblongata ordinarily follow two different roads in the spinal cord; viz., the anterior pyramidal tract of the same side, and the lateral (crossed) pyramidal tract of the opposite side. Considerable variations are found, however, in the numerical distribution of the pyramidal fibres in these tracts of the cord, not only in different individuals, but even in the two lateral halves of one cord. While *semi-decussation of both pyramids* has been most frequently found, Flechsig has also seen partial decussation of only one pyramid, with total crossing of the fibres of the other to the opposite side, and even *total decussation of both pyramids* with entire absence of both anterior pyramidal tracts. The other extreme—total absence of decussation, he has not yet met with, although occasionally but very few fibres did cross to the opposite side. Since the pyramids are now recognized as the tracts of voluntary impulses, this variability in the connection of one side of the brain with the same, or opposite side of the cord, is of great clinical interest. The total area of the pyramidal tracts diminishes as they descend in the cord. The lateral pyramidal tract disappears usually about the level of the third or fourth sacral nerve, its fibres having gradually entered the gray substance. The anterior pyramidal tract disappears at the upper limit of the dorsal part of the cord, sooner or later, according to its original volume; the termination of its fibres is not settled.

A system of fibres running from the nucleus lenticularis, and internal capsule, through the pes peduncle and pons into the pyramid of the same side, and thence down into the spinal cord, is the tract of *Tuerck's descending degeneration;* any lesion of this tract is followed by degeneration of the fibres below the seat of the lesion. As far as Flechsig's researches go, this system of fibres is identical with his pyramidal tracts.* The variability in their topographical distribution in the cord, sheds a new light on the previously found differences in the locality of the degenerated fibres in the cord.

The direct lateral cerebellar tracts. Fibres radiating from the gray substance, especially from the columns of Clarke, collect in a flattened bundle, occupying a narrow zone at the periphery of the posterior half of the lateral column, which bundle is to be found as low as the lumbar part of the cord. Other fibres, however, from the same source, ascend the cord, intermingled with the remaining fibres of the lateral column, without forming a distinct bundle; they are shown to be equivalent to the first-mentioned fibres by the time of their development. Increasing in number as they ascend, both sets of fibres enter the corpus restiforme in the medulla, and as the *stratum zonale* gain its posterior part. Flechsig has traced them no further than the cerebellum, where they apparently run towards the vermis superior. In the *ascending form* of secondary degeneration this system of fibres is one of the tracts involved, any lesion in its course being followed by degeneration of the fibres above the lesion.

The remainder of the lateral columns consists of fibres radiating into it from the gray substance. The lateral border zone of the gray substance receives, besides, fibres coming from the posterior roots, while fibres from the anterior roots enter the anterior mixed region of the lateral column. On this account the area of the lateral columns enlarges considerable at the places where the roots of the spinal nerves contain most fibres; viz., at the cervical and lumbar enlargements of the cord. The fibres of these tracts enter the formatio reticularis of the medulla oblongata.

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*In a recent note in the *Centralbl. f. d. Med. Wissensch.*, 1877, No. 3, Flechsig states, that he has since traced the pyramidal fibres as a compact bundle through the pes pedunculi and internal capsule into the centrum semiovale, in the vicinity of the sulcus centralis.

The main anterior fasciculus receives fibres both from the anterior roots of the opposite half of the cord (through the anterior commissure), and from the anterior horns of the gray substance of both sides. It is continuous with the fasciculus longitudinalis posterior of the medulla.

Goll's columns are distinctly isolated in embryological specimens only as far as the upper third of the dorsal region, but very probably continue to the lumbar enlargement. Their constituent fibres are furnished partly by the columns of Clarke of the same side of the cord, partly by the posterior horn of the opposite side by route of the posterior commissure. Increasing in area as they ascend, they apparently terminate in the "nuclei of the funiculi graciles" in the medulla. This system of fibres (together with the lateral cerebellar tract) is the seat of the *ascending form* of secondary degeneration.

Burdach's columns are composed largely of fibres from the posterior roots, and hence show the greatest area at the enlargements of the cord, where the spinal roots are the most voluminous. But fibres composing these columns can also be traced into the gray substance, radiating towards the anterior horn, the posterior commissure, and the region of the columns of Clarke. The tract terminates apparently the "nuclei of the funiculi cuneati" in the medulla.

As regards the order of development of the different systems of fibres, we cannot follow the numerous details of Flechsig's researches; suffice it to say that the formation of medullary sheaths begins in the cord and gradually extends towards the cerebrum. The first appearance of "medullary white" is observed in the fœtus of 25 centim. length in Burdach's columns. The pyramidal tracts, on the other hand, the last in the cord, are not completed until after birth. About the end of the fourth month after birth all fibres of the brain have acquired their medullary sheaths.

This brief review of the most important facts shows the work to be one of real merit. Notwithstanding its size (over 300 pages), most of the contents are either wholly new or an *exact* reproduction of our hitherto uncertain knowledge on the subjects. But a more systematic arrangement would have enabled the author to avoid numerous repetitions, while making the the book a less difficult, if not more profitable study. H. G.
